IMPACT FACTORS IN THE 21st CENTURY

In the mid-1950s, Eugene Garfield invented the 'impact factor'. Garfield himself acknowledges that the calculation has its flaws, and he has repeatedly reminded us that the impact factor was not designed for many of the uses to which it is currently put. Below, we will define the impact factor, describe some of the ways in which it is used and misused, and suggest a couple of new ways to assess scientific literature.

QUALITY

When the Royal Society in the UK set up its first journal in 1645, we can be pretty certain that the founding fathers didn't wonder what the impact factor might become in the fullness of time. The Society's aim was, and still is, to publish science of the highest possible quality and to make it available to the largest audience possible. In general, quality in a scientific journal is assured by the journal's editorial policy and by the enforcers of that policy. Education, in the broadest sense, was and still should be the goal, and many members of learned societies will be familiar with this principle as one of the key elements in their organisation's articles of association/by-laws/mission statement. So when did the scientific community decide that we had to have a certain impact factor? Does the fact that a paper receives 10 citations mean that it has twice as much 'quality' as one cited five times? Or is it of infinitely greater quality than a paper that is never cited? A paper prompting numerous published criticisms can ironically lead to an increase in a journal's impact factor (if not its reputation!). How is quality defined? One measure might be to see how an article stands the test of time.

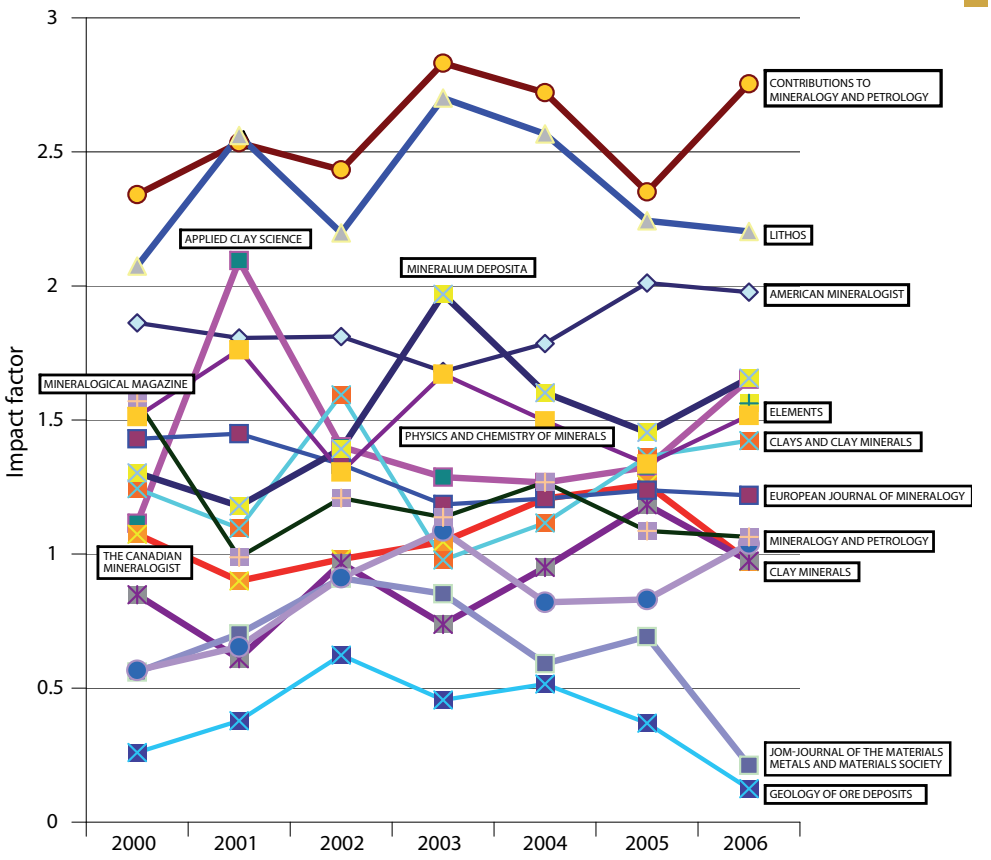
DEFINITION

The impact factor for a journal, e.g. for the year 2007, is defined as the number of citations in 2007 of papers published in 2005–2006, divided by the number of papers published in 2005–2006. So, if every paper published in the journal was cited once in the two-year period after it was published, then the journal would have an impact factor of 1. Garfield and a colleague invented the calculation to provide some criteria for deciding which journals should be included in the Science Citation Index and which should not.

QUALITY INDICATOR?

The impact factor is used as a quasi-indicator of quality:

- By an author to decide in which journal to publish his or her paper
- By an employer to assess the quality of published research of an employee or potential employee
- By funders of research when deciding on the quality of research output of a researcher or group of researchers
- By some librarians when deciding on journal purchases, or more usually, journal cancellations



Recent history of impact factors for 20 journals in the fields of mineralogy, petrology and geochemistry.

So what's wrong with that? Well, if you are an author, simply publishing your paper in a journal with a large impact factor does not mean that your paper will have a larger 'impact' on its audience. There is no evidence to suggest that there is a rub-off effect, i.e. you won't necessarily get more citations because you publish in that journal than if you publish in a journal with a low impact factor. Thankfully, many authors are prepared to ignore the impact factor god and publish their papers in a journal because it has a strong history of publishing work in that area, because they can reach an appropriate audience in that journal, or because of the rigour with which peer review is carried out by that publisher.

In an ideal world, somebody trying to assess your work or research output should examine that work carefully, seeking expert opinion where necessary, and on the basis of considered deliberation, come to a conclusion as to the relevance and originality of the work. In practise, however, such assessment is often based on the reputation or impact factor of the journal in which the work is published. Research funders do likewise. The impact factor is an easy metric to find and deploy.

Many authors know the impact factor of the journal in which they publish. Many are aware of how many times their own papers have been cited. Many are not aware, however, that the more-cited half of papers in any given journal will be cited ten times as often as the less-cited half; in other words, a small number of papers will garner most of the citations in any particular journal.

Here are some interesting points to note:

- Longer and review papers are generally more cited than shorter papers.
- Journals in emerging areas of life and biosciences are more likely to have high impact factors than those in other areas, e.g. Earth sciences. (Journals in the arts and humanities contain very few references and tend not to be widely cited, and so tend not to have high impact factors.)
- Journals in which long reference lists are used (and this ties in with the comment about review papers above) tend to have higher impact factors.
- Journals with a large circulation will do better in terms of citations than ones read by a small audience.

Cont'd on page 139

ically voluminous and crystal-rich flows were extruded. The presence of globules of nephelinitic liquid within the unusually viscous natrocarbonatite flows (transport of the dense silicate globules resulting from the atypically high viscosity of the flows) provided further corrobative evidence for two coexisting magmas at the volcano.

Lava flows from a series of transient lava pools and hornitos then continued to infill the crater till, in 1999, the crater rim was overtopped and natrocarbonatite flowed down the outer slopes at several points. This phase of lava extrusion and overspill continued till early September 2007, when another phase of violent ash eruption began (FIG. 5) and which is still going on (March 2008). Again fortuitously, I had arranged with Roger Mitchell (Lakehead University, Ontario) to be looking at the monogenetic crater field to the east of the volcano. We were easily diverted to the western foot of the volcano to sample the new lapilli that rained down on us. The lapilli have proved to be similar in some ways to those from the 1966 eruption, but their matrix is phosphate rich, as opposed to carbonate rich, and the lapilli matrix, lacking clinopyroxene, is neither nephelinite nor melilitite. For these latest results, see *Mineralogical Magazine* 71: 483-492, 2007.

Yes, I have been lucky. My association with Oldoinyo Lengai has been a continuing voyage of discovery, ranging from the initial discovery of natrocarbonatite in 1960 to the latest clinopyroxene-free material in the 2007 lapilli that will have the IUGS Subcommission on the Systematics of Igneous Rocks scratching its collective head for a suitable name. I have been privileged to see the volcano in all its moods, from quiet flowing of lavas that have the viscosity of olive oil, to the violent ash eruptions of 1966 and 2007. But above all, I was fortunate to have been in northern Tanganyika (as it then was) in "the old days," when the approach to my volcano was across trackless savannah and the voice of the lion was still heard in the night. These days, a dirt road runs past Oldoinyo Lengai en route to Loliondo on the Kenya border, and leads to the settlement of Engare Sero and to the tourist camps near Lake Natron. With the boom in geotourism and the better communications and facilities, the number of people now climbing Oldoinyo Lengai in a single month probably surpasses the total of all those who toiled to the summit in the first sixty years of the last century. Even so, the obliteration of the western "tourist" route by the 2007–2008 ash eruption reminds us that the more approachable Oldoinyo Lengai is still a formidable mountain, not to be challenged lightly. But has it any further geological treasures to yield up? I hope so. As the Roman geographer Pliny said, "*Ex Africa semper aliquid novi* – There is always something new out of Africa."

Barry Dawson
Grant Institute of Earth Science
University of Edinburgh

IMPACT FACTORS IN THE 21st CENTURY *(Cont'd from page 137)*

HOW DO YOU IMPROVE A JOURNAL'S IMPACT FACTOR?

Publish more long papers and reviews. Publish papers describing new or improved techniques; these are sometimes, but not always, big hitters. Publish papers with long reference lists. Make the content available to more people by making it available to all, free of charge. Publish thematic sets of papers in more popular areas. Increase the size of the audience through increased sales (or through inclusion of your journal in e-journal aggregates).

ALTERNATIVES

A possible alternative to the impact factor has been suggested in the UK. The department of the former Chancellor of the Exchequer, Gordon Brown, has suggested that a researcher's quality of output should be based on his/her success at obtaining research funding.

Perhaps of more benefit, to publishers at least, would be the knowledge of readership. A new industry-standard method of counting downloads of journal content (Counter 2.0) has been in operation since early 2006. If, as stated above, the goal is education, then can we not say that the number of times an article is downloaded is at least as valid, and probably more so, than the number of citations? There is not necessarily any correlation between downloads and citations. Some heavily downloaded papers do not turn out to be as highly cited as might be expected if there were a correlation between the two.

A relatively recent publishing phenomenon has been the clamour for access by the public to the results of research carried out by publicly funded researchers. If this comes to pass, then does it not strengthen the case for using a download count rather than a citation count? A paper that has value to the public must serve the goal of education as much as one serving the need of the smaller academic-only community.

Researchers in Los Alamos, and elsewhere, have been working on alternative metrics which will take into account usage as well as citations. Early signs, however, suggest that for subject areas with large numbers of devotees, the impact factor and usage factor correlate (Bollen and Van de Sompel 2008).

The '*h*-index', suggested by Jorge E. Hirsch as a tool for determining theoretical physicists' relative quality, purports to quantify the scientific productivity and the so-called scientific impact of a scientist. It is based on the scientist's most cited papers and the number of citations of them. A scholar with an index of *h* has published *h* papers each of which has been cited at least *h* times. The same index can be applied to groups of scientists, e.g. in a department or university or country. The *h*-factor removes emphasis from a large number of citations for a small number of papers, and considers a larger number of papers.

The '*g*-index' is similar. Given a set of articles ranked in decreasing order of the number of citations that they received, the *g*-index is the (unique) largest number such that the top *g* articles received (together) at least g^2 citations (definition from Wikipedia).

PROBLEMS WITH THE IMPACT FACTOR

None of the major citation-based metrics places importance on the context of the citation. Is the citation included to give background information, or are its conclusions dealt with in depth? Is the citation made in a negative context, as a correction, or to fraudulent work?

And what of the number of authors? The simplest way to increase your *h*-factor, or any other factor for that matter, is to have yourself included as a co-author on as many papers as possible, irrespective of the amount of work you've done on the paper.

DATA MINING

A recent paper by Petford and Adams (2008) describes a study on citation data obtained from the Thomson ISI® science citation database. There is much of interest: citation data have been normalized (Rebased Impact [RBI] index) in different subject areas to a world average for any given year. Of great interest, though, is the fact that 21.4% of all UK papers in the geosciences (*sensu lato*) are uncited (of almost 23,000 papers published from 1995 to 2004). A further 42% of journal articles are cited, but are below the world average. Note that similar performance is noted in physics and chemistry. Thus, although the UK average RBI for geoscience papers is 1.33, above the world average, two-thirds of the material is uncited or cited less than the average.

CONCLUSION

This debate continues to rumble on, and we hear about how key groups, e.g. those responsible for the Research Assessment Exercise in the UK, are moving even more towards metrics systems of evaluating impact and quality. Hopefully, new systems will continue to become available – ones which consider more factors than just citations, e.g. downloads/usage. This, one feels, would level the playing field for all concerned.

Kevin Murphy
(kevin@minersoc.org)
Executive Director, Mineralogical Society

REFERENCES

Bollen J, Van de Sompel H. (2008) Usage impact factor: The effects of sample characteristics on usage-based impact metrics. Journal of the American Society for Information Science and Technology 59: 136-149

Petford N, Adams J (2008) Goalposts on the move. Geoscientist 18(2): 18-21